Today, we will:
- Do some review example problems, partial pressure, mol fraction, flow rates, etc.
- Discuss species mass flow rates, and various definitions of pollutant concentration

Example: Partial pressure

Given:
- The mol fraction of CO (carbon monoxide) in a container with air is 56.0 PPM.
- The molecular weight of CO is 28.0 kg/kmol.
- The temperature is 20^{o}C and the pressure is 99.5 kPa in the container.

To do: Calculate the partial pressure of CO in the container.

Solution:

(a) $y_j = \frac{P_j}{P}$ here let $j = CO$ $y_j = 56.0$ PPM

$P_j = y_j \cdot P$ $y_j = 56.0 \times 10^{-6}$

$$P_j = (56.0 \times 10^{-6})(99.5\ kPa) = 5.572 \times 10^{-3}\ kPa$$

☆ Small! → $\boxed{P_j = 5.57 \times 10^{-3}\ kPa}$

(b) if $\forall = 1.20\ m^3$, calculate $\forall_j$

Soln. $y_j = \frac{\forall_j}{\forall} \rightarrow \forall_j = y_j \forall = (56.0 \times 10^{-6})(1.20\ m^3) = \boxed{0.0000672\ m^3}$

$$\times \left(\frac{100\ cm}{m}\right)^3 = 67.2\ cm^3$$

(c) Calc. the mass of the CO in grams

Soln: ~~Use Ideal gas law~~ :

$T = 20 + 273.15 = 293.15\ K$

$$P_j \forall = n_j R_u T \qquad n_j = \frac{m_j}{M_j} \qquad M_j = 28.0\ \frac{kg}{kmol}$$

$$\boxed{m_j = \frac{P_j \forall M_j}{R_u T}} \ ☆$$

$$m_j = \frac{(5.572 \times 10^{-3}\ \cancel{kPa})(1.20\ \cancel{m^3})(28.0\ \cancel{kg}/\cancel{kmol})}{\left(8.314\ \frac{\cancel{kJ}}{\cancel{kmol} \cdot \cancel{K}}\right)(293.15\ \cancel{K})} \left(\frac{1000\ g}{\cancel{kg}}\right)\left(\frac{\cancel{kJ}}{\cancel{kN} \cdot \cancel{m}}\right)\left(\frac{\cancel{kN}}{\cancel{m^2} \cdot \cancel{kPa}}\right) = \boxed{0.0768\ g}$$

· Concentrations of air pollutants

• mass concentration $C_j = \dfrac{\text{mass of species } j}{\forall \text{ of mixture}} = \boxed{C_j = \dfrac{m_j}{\forall}}$

dim: $\{C_j\} = \left\{\dfrac{m}{L^3}\right\}$ units → $\dfrac{mg}{m^3}$, $\dfrac{\mu g}{L}$, etc.

• molar concentration $\boxed{C_{molar,j} = \dfrac{\#\text{ mols of species } j}{\forall \text{ of mixture}} = \dfrac{n_j}{\forall}}$

dim $\{C_{molar,j}\} = \left\{\dfrac{N}{L^3}\right\}$ units $\dfrac{mol}{m^3}$, $\dfrac{mol}{ft^3}$, $\dfrac{mol}{L}$, etc.

Conversion: since $m_j = n_j M_j$ → $C_{molar,j} = \dfrac{n_j}{\forall}\dfrac{M_j}{M_j} = \dfrac{1}{M_j}\dfrac{m_j}{\forall} = \dfrac{C_j}{M_j}$

$\dfrac{m_j}{\forall} = C_j$

$$\boxed{C_{molar,j} = \frac{C_j}{M_j}}$$

More conversions: For ideal gas mixture

$C_j = \dfrac{m_j}{\forall}$ = mass conc. $(m_j = n_j M_j)$

but $P_j \forall = n_j R_u T = \dfrac{m_j}{M_j} R_u T$

$$\forall = \frac{m_j}{M_j}\frac{R_u T}{P_j}$$

$$C_j = \frac{\cancel{m_j}\, M_j\, P_j}{\cancel{m_j}\, R_u T}\frac{P}{P}, \quad \frac{P_j}{P} = y_j$$

$$\boxed{C_j = y_j \frac{M_j}{R_u}\frac{P}{T}} \quad (1)$$

- Mol fraction y_j is independent of P & T
- Mass concentration c_j is dependent on P & T
- molar " $C_{molar,j}$ is dependent on P & T

☆

Mass flow rate of species j

$\dot{m} = \rho Q$ = total or bulk mass flow rate of the mixture

Define $\dot{m}_j$ = mass flow rate of species j

$$\dot{m}_j = \frac{\text{mass of } j}{\text{time}} = \frac{\text{mass of } j}{\text{vol.}} \frac{\text{vol.}}{\text{time}} = c_j \cdot Q$$

$$\boxed{\dot{m}_j = c_j Q}$$

Caution: This Q is actual Q not the standard Q

Example: Volume and mass flow rate

Given:

actual ft^3/min

- The bulk volume flow rate of an air/ammonia mixture is 1000 ACFM through a duct.
- The air contains 5.0 PPM of ammonia vapor ($M_{ammonia}$ = 17.0 g/mol).
- The temperature is 200.°C (473.15 K) and the pressure is 90. kPa.

(*a*) To do: Calculate the bulk volume flow rate in SCFM.

Solution:

$$Q_{STP} = Q_{actual} \frac{P}{P_{STP}} \frac{T_{STP}}{T} = \left(1000 \frac{ft^3}{min}\right)\left(\frac{90.\ kPa}{101.325\ kPa}\right)\left(\frac{298.15\ K}{473.15\ K}\right) = 559.7 \approx \boxed{560\ SCFM}$$

(*b*) To do: Calculate the ammonia mass concentration.

Solution:

$$\boxed{C_j = y_j \frac{P}{T} \frac{M_j}{R_u}} = \left(5.0 \times 10^{-6} \frac{kmol_{am}}{kmol}\right)\left(\frac{90.0\ kPa}{473.15\ K}\right) \frac{17.0 \frac{kg_{am}}{kmol_{am}}}{8.314 \frac{kJ}{kmol \cdot K}} \left(\frac{kJ}{kN \cdot m}\right)\left(\frac{kN}{m^2 \cdot kPa}\right)\left(\frac{10^6\ mg_{am}}{kg_{am}}\right)$$

$$C_j = 1.9447 \frac{mg}{m^3} \rightarrow \boxed{C_j = 1.9 \frac{mg}{m^3}}$$

(*c*) To do: Calculate the emission rate $\dot{m}_j$ of ammonia into the atmosphere in g/hr.

Solution:

$$\boxed{\dot{m}_j = C_j Q_{actual}}$$

$$\dot{m}_j = \left(1.9447 \frac{mg}{m^3}\right)\left(1000 \frac{ft^3}{min}\right)\left(\frac{0.3048\ m}{ft}\right)^3\left(\frac{60\ min}{hr}\right)\left(\frac{1\ g}{1000\ mg}\right) = 3.30406 \frac{g}{hr}$$

$$\boxed{\dot{m}_j = 3.3 \frac{g}{hr}}$$